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CHAPTER 9: THE ROLE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY

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Introduction

Electronic computers and other information and communications technologies (ICTs) have been important to scientists in their work since their invention (by scientists) in the 1950s. Without powerful machines able to carry out many thousands of calculations in seconds it is unlikely that man would have ventured far into space let alone landed on the moon or devised spacecraft such as the Cassini Explorer and the Hubble Telescope that are currently mapping the Universe. We would not have been able to start decoding the human genome without the ability to share huge databases of genetic information nor design drugs to target specific interactions within the human body without sophisticated three-dimensional computer modelling systems. In fact it would be difficult to identify a scientific development in the past 30 years that did not rely on the use of computers for data processing and storage. The World Wide Web itself was developed by Tim Berners-Lee to facilitate sharing of information among scientists, in this case, particle physicists working at CERN in the 1980s.

Following a similar meteoric rise, the use of ICT now plays a major role within science education. In their summary review of the importance of ICT to UK schools

Ofsted (2009) commend a range of activities found in school science departments that includes the use of digital video cameras to record experiments and employing the video in subsequent presentations, and the use of data logged from environmental sensors within the school building to learn about heat loss and sustainability. They also highlight the use of handheld personal digital assistants (PDAs) to collect data and images by students working collaboratively in class and on field trips. In all, there appear to be five forms of ICT used within school science which are relevant to teaching and learning (Osborne and Hennessy, 2003). These include:

- tools for data capture, processing and interpretation including data logging systems, data analysis software (e.g. 'Insight'), databases and spreadsheets (eg 'Excel');
- multimedia software for simulation of processes and carrying out 'virtual experiments' (e.g. 'Science Investigations 1', 'Chemistry Set', 'Multimedia Science School');
- information systems such as CD-Rom encyclopaedias, the World Wide Web and school based learning platforms;
- publishing and presentation tools (e.g. 'Word', 'PowerPoint');
- digital recording equipment – still and video cameras;

- computer projection technology - interactive whiteboards or data projectors + screens.

Of these, by far the most relevant to the everyday work of professional scientists working in industry, research and manufacture today are the tools for data capture, processing (including modelling) and interpretation. Scientists also rely on information systems such as electronic databases and journals to support them in their research in addition to presentation tools to publish their work. McFarlane and Sakellariou (2002) point out the iterative nature of this process; their model (Figure 9.1) shows how scientists' work with ICT can be used to structure students' experience of science at the school level.

<Figure 9.1 here>

Figure 9.1. A model of the iterative process of science that can be used to structure experience of science at the school level with some examples of uses of ICT (from McFarlane, 2000).

However, developments in ICT are characterized by the speed with which things change and recent advances in computing such as the development of social

networking (web 2.0) tools, grid computing and PDAs have now further changed the way scientists can work. This chapter focuses on these relatively new developments in ICTs that have enabled scientists to change the way they collect, record, analyse and share information as part of their work. It is therefore organized into four sections that acknowledge the key roles played by data including its collection, storage and processing, and communication (of the information derived from the data) in teaching *How Science Works* with ICT.

The first section of the chapter focuses on data collection and includes an acknowledgement of the central role electronic monitoring devices play in logging the data from experiments in locations as diverse as a centrally heated, climate controlled university laboratory and the permanently frozen, wind swept Antarctic wastes. Real time data logging has been central to scientists' understanding of many processes and now, new handheld devices mean that both scientists and students studying science, young and old, can collect and analyse data, on the spot, wherever they happen to be. It includes a vignette from a research project investigating how science teacher trainees explored the potential of PDAs for supporting science teaching and learning.

One aspect then springs to mind: what are the scientists going to do with all the data now being collected and how can it be stored safely and responsibly? The latest mainframe computer installed at the University of Bristol, Blue Crystal 2, has 73 terabytes of storage. That's 73 million megabytes, enough to store the complete

genome sequences of over 24,000 individuals or over 14 million copies of the complete works of Shakespeare. Thus the next section of the chapter addresses the storage and sharing of scientific data. Parallels are drawn for the science teacher attempting to manage good practice in the classroom environment.

The third section of the chapter focuses on the role of ICT in processing large quantities of data. Many of today's scientists work on projects such as modelling protein folding, weather forecasting and brain imaging. Computer-based modelling is also common in schools where it has been found that encouraging students to build models enables them to develop an understanding of both modelling as a process in science investigation and of the scientific ideas that they are attempting to model (Brodie et al., 1994; Webb, 1993). The most complex models such as those used for weather forecasting and climate change predictions are run on networks of powerful computers such as Blue Crystal 2 forming distributed, computer power sharing grids. In addition to producing complex visualisations that aid scientists in interpreting patterns in their data, the grids can also enable collaborative data analysis. There are a number of international projects where scientists, across the globe, are sharing their data with school students to engage them in conducting real science experiments.

Scientists don't necessarily need powerful research or industry sponsored computing facilities, many are finding web 2.0 tools such as wikis and blogs enable them to engage in necessary debate with their peers over social, ethical and environmental impact of their findings. The final section of this chapter considers how the internet

has changed the way scientists publish their work and enabled new avenues for professional discourse. This is being mirrored in secondary schools, where Ofsted (2009) report that students make the best use of ICT in communicating their ideas and presenting their work. This section includes a vignette of a research project investigating the use of online discussion for teaching about ethical issues in science. Lastly it addresses the need for science teachers to teach their students how to check online publications for reliability and validity.

Data collection

Collecting data through observation is central to scientists' work. They use a wide range of electronic sensors to detect and record physical and chemical changes in their investigations. Similarly, much use of ICT in school science lessons has centred on data logging where software running on a laptop or desktop PC is used to display recordings from simple sensors measuring temperature, light, pH levels etc. Whilst such experiments can seem complex to set up, for sensors need first to be plugged into an interface that must be connected to the computer; they are generally thought to provide valuable learning opportunities. Frost (2010) hosts details of over 40 data logging experiments taken from UK science classrooms on his Dataloggerama website. Using such tools for data capture and display frees students from laborious processes (Osborne and Hennessy, 2003) that include the need to regularly take readings and to plot the relevant points on a graph of their data. This freedom allows students working together to discuss the shape of a graph as it emerges in real time on

the computer screen. Newton (1997) found such talk can help develop students' appreciation of the meaning of patterns in their data and their skills in communicating about it.

Data logging sensors can also be connected to handheld computers or PDAs and taken outside the classroom to collect data in the real world environment. This allows students to collect authentic data and enables them to see 'on the spot' how their recordings relate to the processes being observed. From his experience of the Science Learning in Context project, Krajcik (2001) describes this learning in real world environments and enabled through the use of handheld devices as contextualized, active and constructed through interaction with others. The project itself involved students from schools in Michigan and Washington using handheld Palm Pilots with probeware for a range of data logging activities outside the classroom. In a typical example a class of grade seven students monitored the quality of water in a nearby stream with pH, temperature, conductivity and dissolved oxygen probes (sensors). Their teachers reported that the students showed enhanced understanding and motivation for learning in this way (Novak and Gleason, 2001). In particular the teachers were impressed by the growth they observed in their students' ability to analyze and synthesize collected data.

More recently the inclusion of Global Positioning System (GPS) receivers in handheld devices such as mobile phones has enabled locations as well as data to be recorded. In the Participate project (Woodgate et al., 2007) Year 10 students at a

school in Bath logged carbon monoxide levels and GPS co-ordinates on their routes to and from school. These were then displayed for the class on Google Earth.

Woodgate et al. (2007) report that such visualizations not only made previously invisible information more concrete and more understandable to the students but also supported them in reflecting on and discussing their findings. The pupils themselves indicated that participating in the project had helped them learn that environmental issues were part and parcel of their everyday lives. In another GPS enabled project, Wildkey, researchers worked with 937 children aged from 6 to 14 using PDAs with integrated GPS running digital species identification keys to identify wildlife and record its location (Hughes, 2007). The data collected could be uploaded to a desktop computer back in the classroom and maps or graphs produced e.g. by using a Google Earth mash up (a mash up is the combination of data from two or more digital sources to create a new service). The children's teachers agreed that using WildKey on handheld computers provided a worthwhile learning experience and motivated their students. They also agreed that it provided an improvement on paper-based keys and that having access to such a resource would enhance their own confidence in leading wildlife identification sessions with their pupils.

Data logging has recently received an unanticipated boost from the Apple iPhone released in the UK in 2007 that has become the latest 'must have' gadget for school Physics teachers. Its internal accelerometers sense angular rotation and acceleration. This has led to teachers showing off apps such as Dynolicious to their classes. This displays recordings of the teacher's car's speed and charts its acceleration. Roller

Coaster Physics which will graph how the acceleration and velocity of an individual changes as the person carrying it rides a roller coaster or simply gets in a lift is also becoming popular.

Thus handheld computers, PDAs and similar mobile devices can be seen to offer contextualized, constructive, authentic opportunities for science learning. Sharples et al. (2005) propose a theory of learning for the mobile age that highlights interaction between learner and context, as well as between learners, and between learners and their devices. Teachers need to be aware of the importance of concepts of control, context and communication to interactions involving learning via mobile devices both outside the science classroom and when the students return to it.

Can PDAs support science teaching as well as learning?

Handheld computers or PDAs are becoming popular in professions such as medicine and law where access to an extensive body of knowledge is needed at varying locations. It is clear that trainee science teachers too need access to information such as course documentation, timetables, emails from their tutor or mentor, pupil attendance records and grades, science constants and formulae exactly when and where it is needed to support their teaching or learning. This information may come from applications on the PDA, dedicated science software or the Web, especially via a course-linked VLE, or from previously recorded pupil data or via communications with peers and tutors.

Science teachers in a secondary school and small group of teacher trainees were loaned internet enabled PDAs in a small scale study (Wishart, 2009) set up to investigate whether such devices could support student science teachers in their teaching and learning. Results were varied however, both teachers and trainee teachers recognized the potential of the PDA for learning and teaching support as described by Naismith et al. (2004) and identified the same three software applications as central to this potential as had been identified in an earlier study (Wishart, Ramsden and McFarlane, 2007). These were the calendar or diary scheduler for organizing yourself (shown in Fig. 2), the spreadsheet of attendance or mark book for organizing your students, and the use of a word processor to make notes on information and events immediately after they are encountered (shown in Fig. 3). This latter activity was particularly supportive of trainees' learning, on teaching placement they would make notes in separate files on their PDAs, as shown in Fig. 3 and later, through a process linked to further research and reflection, reconstruct those notes into a reflective essay demonstrating their learning.

Figure 2. A teacher's timetable

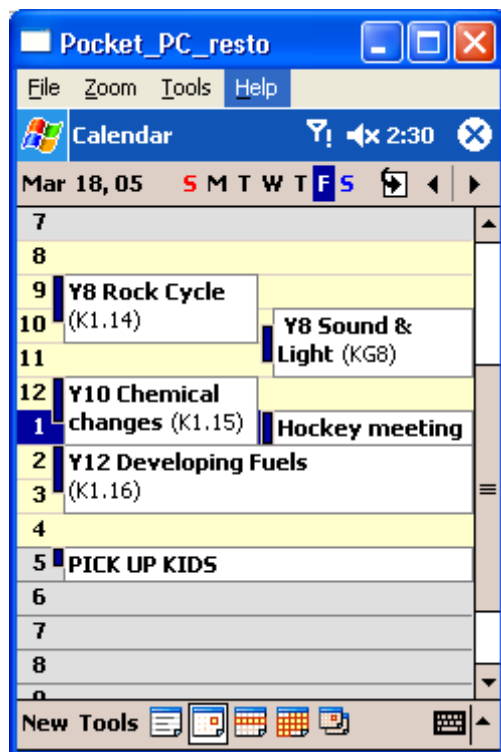
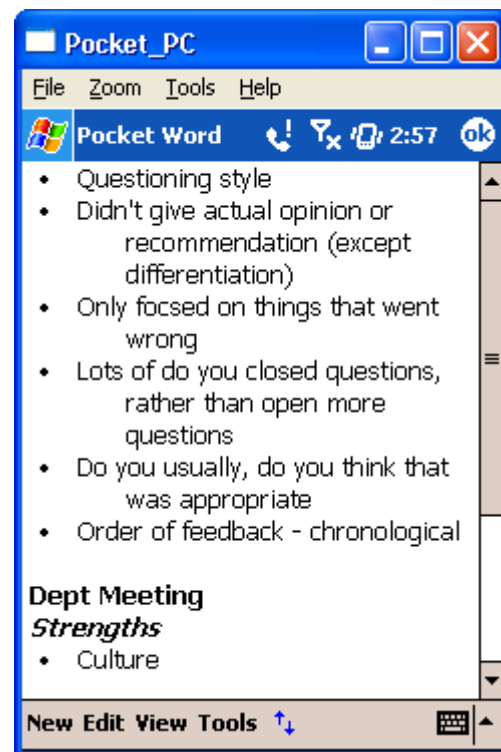


Figure 3. A student teacher's notes



The effectiveness of these kinds of activities is reinforced by this student's report "During teaching practice I have found myself constantly bombarded with new and noteworthy information (e.g. scientific facts, ideas for teaching approaches, school procedures, evidence for QTS standards etc.). The PDA has allowed me to keep meaningful notes of this information, and structure the information in a way that allows me to access it easily."

Teachers also found note taking on the PDA useful e.g. when meeting colleagues by chance in the corridor between lessons. Other activities had individual champions. One member of staff was very emphatic about how useful it was to set up a class administration system in Excel on a desktop computer and synchronise it to the PDA so that could be quickly and easily updated during lessons. He used multiple worksheets for attendance, grades, practical science skills achieved and commendations. Another teacher was particularly positive about his use of the camera, taking photos and video clips of lesson activities to later play back to his students in revision classes.

Lastly, several of the trainee teachers reported a feeling of confidence about their use of the PDA, especially being able to access the Internet wherever they happened to be for both personal and professional information. Also, the ability to use and then hide the PDA back in a pocket or bag led to it being perceived as an educational technology that was more manageable in front of students than a desktop computer.

Storing and sharing data

Data logging implies both recording and storage of data. It is important that scientists and teachers understand how setting up initial parameters such as sample rate can affect the amount of data that needs to be stored. Data logging equipment now found in schools can check, say the temperature of a liquid, up to 50,000 times a second, two sensors accidentally set at this rate are going to produce 360 Mb of data per hour. Video data too produces files of huge sizes sufficient to overload a school network in seconds if stored without due care and attention. Researchers in a recent project, Bioethics Live! (BEEP, 2010), that involved pupils producing video clips as part of learning about ethical debates in science, observed the students lose their work as they saved their edited video to the default network drive rather than to the computers' hard drives as they had been instructed. However, once safely stored in electronic format on World Wide Web servers, data resulting from scientific experiments can readily be widely shared.

The potential for increasing the scope and scale of research by globally sharing digital research data from publicly funded projects was formally recognized by ministers for science from the thirty-four countries of the Organisation for Economic Co-operation and Development's Committee for Scientific and Technological Policy in 2004 (OECD, 2004). Scientists across the world have agreed to support the creation of research data archives that can promote scientific progress through underpinning future investigations, encouraging scientific inquiry and providing resources for

education and training. Additionally, scientific journals such Science and Nature now support the need to archive and collate published data for the use of the scientific community. This policy of open access reaches beyond the research community. Currently many ongoing scientific endeavours such as NASA, BBC Springwatch and the British Antarctic survey are making their data available in a form accessible to science teachers for use with their pupils directly as it is captured. Other science projects or resources such as the Faulkes telescope (2010) and Jason Science (2010) have been set up specifically to share data between scientists, teachers and school pupils.

Data sharing between schools is also easily achieved via the internet. In the Sense project (Woodgate et al., 2007), a forerunner to the Participate project described earlier, children, aged between 9 and 14, in Nottingham and Sussex shared and compared their environmental monitoring data. They also discussed their data with a pollution expert remotely. It was found that, as well engaging in authentic scientific inquiry, the pupils from different schools who had engaged in similar processes came to understand new perspectives on their own and others' data. A much larger project, Kids as Global Scientists, involved 3,500 school children in collecting weather data across the United States. The students measured and shared their observations on wind speed, temperature, air pressure and precipitation as well as engaging in online communication about their results with professional meteorologists (Mistler-Jackson and Songer, 2000). An in-depth investigation of one Grade 6 class participating in this project concluded that the authentic nature of the project, communication with

professionals, and collaboration among students supported science content knowledge gains and opportunities for the development of self-efficacy. Such projects do not have to involve creating complex websites and online data repositories. Jarvis, Hargreaves and Comber (1997) found primary school children from 6 different primary schools collaborated successfully by email to log varieties of moths found in their different local habitats.

This use of ICT in education, to enable local and remote communication and collaboration on scientific topics and with scientific data has been defined as eScience (Woodgate and Stanton Fraser, 2005). Underwood et al. (2008) point out the need for considerable preparation on the part of the teacher for planning on engaging in eScience in the classroom. They note the bulk of the teachers' time spent on eScience activities (46%) involved locating and/or creating materials such as multimedia, worksheets, lesson plans and data recording proformas that were intended to make the activity accessible, appropriate, relevant and engaging for specific learners. Other key activities involved matching the science activity to curricular requirements, co-ordinating collaboration and communication (global time zones can be a particular issue), manipulating data into a format suitable for pupils, managing equipment and, last but not least, testing equipment and fixing breakdowns. This final activity comprised 25% of time spent and remains a significant challenge to educators. Issues noted included the need to check that the 'chat' or video conferencing software is allowed on school networks, to check that batteries are charged, to learn how to 'wake up' the PDA and to wait for an initial GPS fix. As

with the storing of video noted earlier, these technical issues that bedevil pioneering teachers and educational researchers should diminish with practice.

Internationally, areas where collaboration and sharing of previously recorded data between scientists are proving fruitful include the study of climate change and the mapping of the human genome. In particular the study of climate and environment is ideal for collecting and sharing data and a good starting point for a simple eScience project in school. On a more global scale, the World Data Center system comprises 52 centres across 12 countries which store baseline information for research by international scientists, especially for monitoring changes in the geosphere and biosphere. The Globe program (2010), set up in 1995 to engage schools with authentic science inquiry projects supporting research scientists is now established as one of the leading international eScience projects. Having involved more than 7,000 schools in 100 countries at the time of writing, it is now planning a two year student research campaign on climate change starting in 2011. The project team expects to recruit more than a million students, empowering them and their teachers to engage in meaningful and relevant research to enhance climate literacy and understanding. Evaluation of the Globe program (Penuel et al., 2006) suggests that, for effective student learning and engagement in eScience, teachers must make time for teaching subject matter content and considering practical implementation issues in their planning. Additionally teachers may need support in setting up equipment and in 'localising' the project aims within their classroom context.

One of the most well known examples of a collaboratively built data resource is the Human Genome Project (HGP). Started in 1990, at an estimated cost of \$3 billion, it aimed to sequence the human genome to find out the exact structure of the entire DNA in a human cell. Therefore, the project needed to identify all the 20,000+ genes in human DNA and to determine the sequences of the base pairs in each gene (approximately 3 billion). To do this, scientists had to devise new software for data analysis and to create vast databases. About two-thirds of the HGP was completed in the United States; other scientists around the world including the UK, Germany, France, Japan and Canada were allocated individual chromosomes to sequence. The project, originally planned to last for 15 years, was actually completed in 2003 because scientists developed improved techniques for sequencing the genes. It has resulted in shared understanding of the human genome, inherited disorders and a variety of gene therapies across the world. However, scientists and science teachers need to be aware of ethical considerations over the storing of such data. Much scientific data like the DNA sequences collected from individuals by the HGP has impact beyond its intended purpose. In particular, there are issues with privacy and confidentiality. Scientists and health professionals gaining access to genetic data must keep it confidential and store it safely. For example, insurance companies would be particularly interested in discovering whether an individual has inherited a tendency to develop a particular disorder. In the UK the storing of personal data is regulated by the Data Protection Act (1998) which contains specific data protection principles that require that data is processed only for the purposes for which it was acquired, kept up to date and stored securely.

Processing data: analysing and modelling

One key aspect of ICT that has proved immensely useful to scientists is the speed with which data can be processed. Many science investigations involve recording observations, usually repeatedly to ensure reliability, and then using them in further calculation. In both science laboratories and schools the use of computer software such as spreadsheets to do this has freed up time which can be used by researchers and learners to focus on the underpinning science concepts. Though it should be noted that pupils need to be specifically directed to make the best use of this time (Newton, 2000). Creative ways in which teachers used this ‘time bonus’ include sharing results, prompting analysis and discussion, and generally emphasising the interpretation of results with associated thinking about the underpinning science (Rogers and Finlayson, 2003).

The vastly increased speeds of data analysis now available have led to the popularity of modelling as a process for developing science knowledge. Scientists developing new drugs or attempting to predict the behaviour of weather systems, for example, can build digital three- dimensional images of possible interactions and try out many possible scenarios. In schools, spreadsheets enable speedy, multiple calculations allowing pupils to practice “what if?” scenarios where they change the parameters of a theory-based mathematical model and engage with the underpinning science as they review the outcomes. Spreadsheet models commonly seen in school science

classrooms include predator-prey relationships, projectile motion and dietary analysis. In their analysis of English science teachers' use of ICT in a range of lessons resulting from a national training programme, Rogers and Finlayson (2003) found that more able pupils in particular were extended by the opportunities that spreadsheet modelling enabled for prompt reflection on the results and further exploratory thinking. Teachers also frequently recognised that whilst using an ICT model that engaged the more able, they had more time to give attention to the lower achieving pupils.

However, Sins et al. (2005) point out that students don't always find modelling easy. In an in-depth investigation of 11th grade students modelling how friction affects an ice skater they found that students working on building their own model tended to focus only on adjusting the model parameters to fit the empirical data they had been given. Sins et al. (2005) concluded that teachers need to scaffold this kind of task carefully to focus their pupils' attention on relevant prior knowledge.

Moving beyond mathematical models and use of spreadsheets, Osborne and Hennessy (2003) note that specially designed modelling tools can provide dynamic, visual representations of data collected electronically or otherwise. Use of these tools in the classroom offers immediate feedback to pupils, and introduces a more experimental, inquiring style in which "what if?" trends are investigated and pupils' ideas are tested and refined. Such models used to visualize and simulate underpinning science processes support children's learning through immediate feedback and

through making the invisible (the movement of particles in a sound wave or during evaporation for example), visible. These types of simulations are now widely available from science teaching resource websites. Teachers in Rogers and Finlayson's (2003) survey often cited their use in an investigative approach to task design where pupils are encouraged to make predictions and then use the software to test them, as a successful teaching strategy. Other teachers and researchers have created specialist computer based simulations that model the processes of scientific inquiry in order to investigate the potential role for ICT in teaching *How Science Works*. In particular these generate simulated data often accompanied by context relevant images and animations for students to analyse. Some successful examples include the Euroturtle Virtual Field Station (Poland, la Velle and Nichol, 2003) and Blast – a simulated gene sequencing tool (Gelbert and Yarden, 2006). However, it is important to note that a theoretical science model underpins any simulation of this kind. Hennessy et al. (2007) highlight one teacher's concerns about the predictability of the dataset programmed into the simulation of a school laboratory experiment that he was using to study the effect of temperature upon enzymes. The teacher also disclosed his pleasure that a number of his more able students realised this limitation of computer models. Tinker (1993) suggests that the study of modelling itself should be part of the science curriculum so that pupils understand how models are constructed, their utility and their limitations.

Computer visualisation tools can be used with data as well as models. Colours are used to indicate subtle differences in observations of temperature, pressure, density,

conductivity, depth and it is now common to see brightly coloured satellite images, body scans, weather charts and digital micrographs. With the processing power of grid computers working in parallel it is now possible for scientists to work collaboratively in global teams on visualizations shared over the internet. Recent research highlights from the Open Science Grid (2010) include DNA sequence analysis to identify new viruses, analysis of laser interferometry data to detect gravitational waves and the study of elementary particles through analysis of nuclear decay. The CoVis Project (Pea, 2002) was set up to understand how science education could take advantage of these technologies. It brought together teams of researchers from two universities, a science centre, a telecomms provider, teachers from over fifty middle and high schools in the United States and thousands of pupils. Pupils were provided with a range of collaboration and communication tools. These included: desktop video teleconferencing; shared software environments for remote, real-time collaboration; access to the resources of the internet; a multimedia scientist's 'notebook'; and scientific visualization software. The project aimed to develop new curricula and new pedagogical approaches that could take advantage of project-enhanced science learning via collaborative visualization supported by high performance computing and communications tools. The researchers found such project-enhanced science with its model of science learning via cognitive apprenticeship (with pupils guided, both by their teachers and by remote mentors, to think about science in many of the ways that scientists do) to be a fundamental pedagogy for achieving deeper learner understanding and distributed intelligence among the science learning community. In contrast to the common 'course delivery'

models of instruction and distance learning, the advantage of such communities is that learning is situated with respect to community-based goals and activities in which knowledge is developed and used.

Sharing results and making decisions

The final stage in McFarlane and Sakellariou's (2002) iterative model of the process of science that can be used to structure the use of ICT in school science (Fig. 9.1) comprises the use of ICT tools such as word-processors and desk top publishing software for sharing experimental results. Publication of findings is important to the development of shared scientific understandings both in school and internationally. It has already been noted that the World Wide Web itself arose from the need for scientists to share the results of their research. Students in school are expected to write up their experimental work. The use of a word-processor, especially with teacher generated templates to scaffold their work, can be supportive here. Also students are often encouraged to present their findings to the class. Typically a PowerPoint slide show is created though this has led to concerns in some classrooms that children can engage more with choosing a font than with explaining the underpinning science. The web itself offers many opportunities for publication and can be used in schools to provide an authentic context for children's writing. For example, in the final phase of the Kids as Global Scientists project mentioned earlier (Mistler-Jackson and Songer, 2000), children produced an online newspaper to share their personal stories and expertise. Additionally features of word processors such as

grammar and spelling checkers, text to speech and word prediction can be used to support the writing processes of children with learning disabilities (MacArthur, 1996). Nor are students restricted to reporting in text based media. In the Bioethics Live! project (BEEP, 2010), mentioned previously, teachers reported students showing their videos on the BEEP website to both friends and family and, at the time of writing, there are nearly 3,000 video clips of school science projects on YouTube.

Research scientists in universities and industry aim to publish their work in academic and professional journals. Their publication record is tremendously important to a scientist for the quality of their work is often judged by it. Before a paper can be published in an international, academic journal it is subjected to the process of peer review. This is where other scientists with expertise in the relevant field read through and check that the work is of sufficient quality and worthy of publication. Many key journals such as Science, Nature and the BMJ have online versions. However, the World Wide Web has also enabled those scientists who are concerned that the peer review process takes too long, or that journals cost too much, to publish their results for open debate. The Directory of Open Access Journals (2010) started by a Swedish University now has links over 1,700 academic journals many of which are peer reviewed.

In fact ICT has supported online sharing and debate since the first bulletin boards were developed in the 1990s. Today scientists are quick to take advantage of new technologies such as web 2.0, to help them disseminate their findings. For example

NASA publishes more than 20 blogs, the Large Hadron Collider runs its own blog ((US/LHC blog, 2010) that people can also follow via Twitter and a group of international climate scientists have set up RealClimate (RealClimate, 2010), a commentary site with a blog and a wiki. Many teachers too have created blogs in order to provide their pupils with science resources and news that can be accessed any time from outside school. Examples include teachers from North Chadderton School (PlanetScience Support, 2010) who provide support and resources for Key Stage 3 and 4 science teachers in England and The Frog Blog (St Columba's College, 2010), a more personal look at science in the news, from St. Columba's College in Ireland. Richardson (2006) points out that this explosion in blogging means teachers need to be literate in the ways of web publishing. This means knowing how to check a web source for authenticity, bias, reliability and validity, knowing how to manage information in quantity and how to model being a producer, editor and consumer of web based information.

Using online discussion to teach about ethical issues in science

Online discussion between scientists has developed from the rather stilted Internet Relay Chat and Bulletin Boards to instant messaging via Facebook or MSN. Threaded discussion boards were set up by a team based at the University of Bristol to investigate whether online discussion could provide science students with a realistic context where they can practise dialogue and develop their arguments before having to produce them in an examination. The boards were linked to two websites containing background information on ethical issues to support students and their teachers with their discussions.


beep BioEthics Education Project


peep Physics & Ethics Education Project


discussion

 Username: Password:

It was found (Wishart et al, 2007) in a survey of eight schools using the biology site, the Bioethics Education Project (<http://www.beep.ac.uk>), that students and their teachers really liked the design and ease of use of the main site. However, most were unwilling or unable to take the time necessary to find out how to make the most of the opportunities for online discussion. However, the two teachers that did use the online discussion were very positive about the results of the activity. Their students' feedback was also positive. Topics that they had discussed included abortion, euthanasia, human reproduction, when life begins, hedgerows, the human genome and global warming. In fact five students cited the discussion opportunities as being the best thing about using BEEP. These two schools' students also displayed the greatest skills in developing arguments; their schools were clearly those where practice of skills in argument was an overt part of their science learning experience.

In a second study comparing the use of online discussion with face to face discussion, Wishart et al (2009) found that teachers still appeared reluctant to let their students experiment with online discussion unsupervised. However, within their somewhat smaller than expected sample of ten discussions, the students' dialogue in online discussions clearly demonstrated higher levels of argumentation than that in face to face discussions. Online discussion regularly reached Level 5, the highest in the framework put forward by Erduran, Simon and Osborne (2004) for assessing the quality of argument in students' work in science. Students reported they learned slightly more from online discussion than face to face discussion, a result that was confirmed by their teachers. Wishart et al (*ibid*) proposed that the asynchronous nature of online discussion is particularly important to developing an evidence based argument as it enables longer, more thoughtful contributions than were found in the face to face discussions.

Conclusion

In summary, this chapter has shown that teaching *How Science Works* in school through ICT can engage pupils and enhance learning in many ways. Different software packages and applications can be deployed effectively by science teachers to scaffold their pupils' learning as they move through the investigative science inquiry cycle. It helps if teachers plan for the key roles played by data (including its collection, storage and processing) and communication (of the information derived from the data) in their teaching of investigative science through ICT.

Additionally, schools may well see more software available to scaffold science inquiry. For instance, the Web-based Inquiry Science Environment (WISE) is designed specifically to harness opportunities offered by the use of ICT to support students' learning through science inquiry (Slotta, 2004). Researchers focused on using multimedia and online collaboration to support the process of knowledge integration across scientific activities of observation, analysis, interpretation, reflection and evaluation. They aimed to make the processes of scientific thinking visible with inquiry maps, evidence pages, models, pop up prompts and hints for analysis and reflection, argument representation and peer review tools. The resulting WISE project's library of investigatory science projects and activities has been well received in hundreds of North American schools.

New ICT tools such as handheld computers and mobile phones, too, are now having an observable impact in schools. In the UK, the PI (personal inquiry) project (Anastopolou et al., 2009) is currently examining the opportunities for science inquiry learning supported by personal, mobile devices such as netbooks and handheld dataloggers. The associated online toolkit comprises a scripted set of activities for secondary school children that follow through the complete scientific inquiry process of setting out a research question, data collection, data analysis, presenting conclusions and evaluation. The personal aspect is highlighted with activities investigating fitness and healthy eating coming under the topic of ‘Myself’ and different environmental investigations brought together under ‘My Community’. Early results show that using personal technologies to support personally relevant activities that bridge home and school contexts was very engaging for most students but care needed to be taken with the ‘Myself’ activities to ensure they were not too personally revealing.

Thus it appears that, as Osborne and Hennessy (2003) foresaw, the new school science curricula are beginning to enable a stronger link between science-as-it-is-taught and science-as-it-is-practiced. As seen in this chapter, researchers in science education and teachers are seizing this opportunity for the integration of ICT within the science curriculum to access information and data and to support their interpretation and critical evaluation. This is necessarily accompanied by a change in pedagogy that focuses on the inclusion of the interactive use of ICT to support and develop school students’ scientific observation, reasoning and analytic skills.

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